An Analysis of the Impact of a Disaster at the Pilgrim Nuclear Power Plant on the Economy of Cape Cod

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This paper was prepared for the Advisory Commission of the Cape Cod National Seashore to promote discussion and encourage public participation in this topic.

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I. Executive Summary

This is a report on the potential economic impacts of an accident at Pilgrim Nuclear Power Plant on the communities of Cape Cod, focusing chiefly on the key industries of tourism and real estate. Impacts are estimated by sensitivity analysis with boundaries based on previous accident outcomes. Key findings include:

- The economy of Cape Cod is highly dependent on tourism, with tourism and travel-relating industries consisting of 12 percent of Gross Regional Product (GRP) in 2011. Real estate, especially retirement and recreational, is also a major industry, with Cape Cod containing 8 percent of Massachusetts's total taxable property wealth.
- Tourism is highly vulnerable to changes in perceptions of safety and security. In the case of an incident generating highly negative media coverage, such as radioactive contamination, it is likely that the tourist industry on Cape Cod will be heavily impacted for a period of several years.
- In case of an accident, 51,329 Cape Cod residents live within 20 miles of the plant, and all 215,888 residents live within a 50-mile radius. If an evacuation is required, the only two routes of egress are the Bourne and Sagamore bridges, both of which are within 20 miles of the plant.
- The current Emergency Planning Zone (EPZ) covers only a 10-mile radius around the plant; in the case of the Fukushima disaster, plumes of radiation spread up to 30km (18 miles).
- The risk of a reactor-damaging earthquake at the site is approximately 1 in 14,000 per year. The greatest risk at the plant is that of an accident involving the spent fuel pool, which holds highly radioactive spent fuel rods at higher and higher densities due to the lack of a long-term storage facility.
- A small-scale release of radioactive material could result in an estimated $741 million to $1.6 billion loss in tourist expenditures, and a loss in tax revenue to the State of Massachusetts of $23 to $62 million over five years.
- In the case of a large-scale disaster, Cape Cod is estimated to lose $2.2 to $12.1 billion in tourist expenditures and $45 to $71 billion in output over 10 years. This would cause a 1-1.5% average contraction in Massachusetts GDP, possibly resulting in a recession. In

addition, Massachusetts could lose $5-8 billion in tax revenues, in addition to indirect effects which could be even greater than direct effects.

II. Summary and Background

Pilgrim Nuclear Power Station

The Pilgrim Nuclear Power Station is located in Plymouth, MA. It was built in 1972 by Boston Edison, and in 1999 it was sold to Entergy Corporation as part of the deregulation of the Massachusetts electrical industry in 1997[1]. Currently, Pilgrim has a production capacity of 685MW, making up 5% of the Commonwealth's total capacity, and producing nearly 14% of its net electrical output[2].

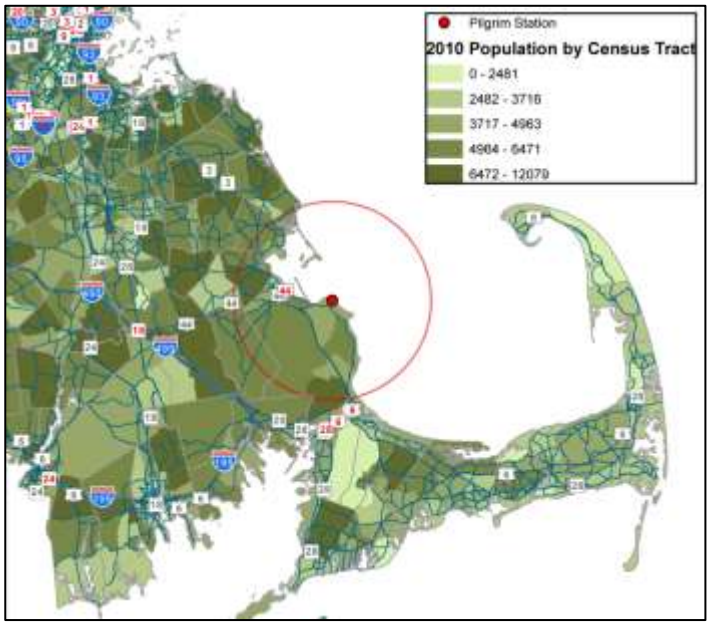

Figure 1: Population distribution in Plymouth and Barnstable Counties, indicating major roads and the 10-mile EPZ surrounding Pilgrim

On January 27, 2006, Entergy Nuclear Generation Company (ENGC) submitted an application to re-license Pilgrim Station for operation; the previous license was set to expire on June 8, 2012[3]. The application was subsequently accepted by the NRC and in May 2012, the station's operating license was extended until 2032[4]. However, before the acceptance of the application, on March 11, 2011, a massive earthquake off the coast of Japan produced an enormous tsunami, which caused cascading failures of critical equipment at the Fukushima Daiichi nuclear power station in Fukushima Prefecture, Japan, that

[1] "An Act Relative to Restructuring the Electric Utility Industry in the Commonwealth" https://malegislature.gov/Laws/SessionLaws/Acts/1997/Chapter164
[2] "Massachusetts Nuclear Profile 2010," http://www.eia.gov/nuclear/state/massachusetts/
[3] "Pilgrim Nuclear Station License Renewal Application," Entergy Nuclear Generation Company, submitted to Nuclear Regulatory Commission, http://www.nrc.gov/reactors/operating/licensing/renewal/applications/pilgrim/pilgrim_lr_.pdf
[4] "POLL: NRC votes to renew Pilgrim nuclear power plant's license," *Patriot Ledger*, http://www.patriotledger.com/topstories/x1832947103/License-renewal-to-come-for-Plymouth-Nuclear-Power-Station

eventually led to a series of core meltdowns. Ultimately, this resulted in a large-scale release of radioactive material[5]. Details of the Fukushima Daiichi accident are discussed further in this report.

The disaster provoked a global re-evaluation of the potential risks of nuclear energy; Pilgrim Station and Fukushima Daiichi use the exact same GE BWR Mk I reactor and containment design, and so after the accident many community members and activists demanded a halt to the re-licensing process until the impact of the Fukushima disaster could be evaluated in the context of Pilgrim. Massachusetts Attorney General Martha Coakley filed an appeal[6] of the renewal decision along those lines, which was subsequently rejected[7] by a federal appeals court.

The re-licensing of the plant is of particular interest not just to the communities surrounding the plant, but those on Cape Cod as well; there exists a possibility that a major accident could spread radioactive material south towards the Cape. Due to the geography of the area, any evacuation route would not only have to cross areas of possible contamination (Figure 1), but during the tourist high season, traffic would all but stop on the only two routes crossing the Cape Cod Canal, potentially trapping hundreds of thousands.

Additionally, the Cape Cod economy is highly dependent on the tourist industry and seasonal and recreational real estate markets, which could be highly vulnerable to the perception of radiation risk and property devaluation. This impact report assesses the main likely factors for a severe accident at Pilgrim and estimates some associated economic costs, with a specific focus on the tourist and real estate industries.

III. What's At Stake?

The Cape Cod Economy: Trends over the Past Decade

The economy of the Cape has always been highly dependent on visitors and prospective homebuilders. The resident population numbers 215,423, but during the peak summer months, the

[5] Strickland, Eliza, "Explainer: What Went Wrong in Japan's Nuclear Reactors," *IEEE Spectrum,* http://spectrum.ieee.org/tech-talk/energy/nuclear/explainer-what-went-wrong-in-japans-nuclear-reactors

[6] Young, Colin, "Attorney General Coakley challenges relicensing of Pilgrim nuclear plant," *Boston Globe* via *Boston.com,* http://www.boston.com/metrodesk/2012/06/18/attorney-general-coakley-challenges-relicensing-pilgrim-nuclear-plant/JSGHIJURwGXyz2E2XQ2E4O/story.html

[7] " Court denies Coakley's appeal of Pilgrim plant license renewal," *Patriot Ledger*, Feb 26, 2013, http://www.patriotledger.com/news/x694775936/Court-denies-Coakley-s-appeal-of-Pilgrim-plant-license-renewal

seasonal population can swell up to over 500,000[8] on any given day. The largest industries on the Cape are therefore those related to tourism and real estate: retail, food service, travel accommodations, construction, and transportation.

As a result of this reliance on a small number of key industries, the 2008 recession hit Cape Cod especially hard, causing a significant decline in home prices and disposable income for travel, resulting in downturn in GDP and employment. Although there has been a gradual shift into new industries, such as arts and financial services, Cape Cod is still heavily reliant on attracting and keeping visitors, property investors, and retirees.

Table 1: Total Assessed Values for Massachusetts and Barnstable County, 2011 (in Millions of Dollars)

Barnstable County	
Residential	$68,138
Commercial	$5,130
Personal	$1,264
Industrial	$425
Total	**$74,964**
Massachusetts	
Residential	$748,316
Commercial	$103,012
Personal	$26,286
Industrial	$30,045
Total	**$907,712**
Percentage of Massachusetts Total Land Value in Barnstable County	
Residential	8.86%
Commercial	4.61%
Personal	4.72%
Industrial	1.41%
Total	**8.01%**

Data from Massachusetts Department of Revenue

[8] Cape Cod Commission, *Cape Cod Comprehensive Economic Development Strategy (CEDS): 2012 Annual Report* (2012), 18

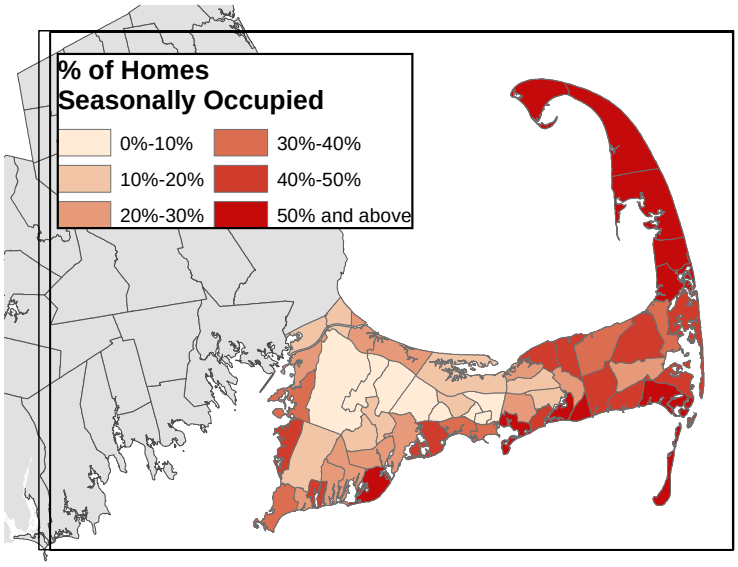

Figure 2: Distribution of seasonally occupied housing on Cape Cod, by Census Tract (2010)

Real Estate Characteristics

There are a total of 161,015 residential housing units on the Cape, although only 94,569 are occupied by either owners or renters—the rest are mostly seasonal second homes belonging to non-residents, distributed mostly along the eastern edge of the Cape, in Provincetown, Truro, Wellfleet, and Eastham (Figure 2), while most of the permanent residents and businesses are concentrated in Sandwich, Barnstable, and other areas of the western Cape.

The total value of all of the taxable property on the Cape is nearly $75 billion[9], mostly in residential real estate, which is fully 8% of the total taxable property value in the Commonwealth (Table 1). Median home values are highest along the eastern edge of the cape, where seasonal housing is concentrated.

[9] Massachusetts Department of Revenue, *Massachusetts Municipal Assessed Values 2003-201,* *https://dlsgateway.dor.state.ma.us/DLSReports/DLSReportViewer.aspx?ReportName=AverageSingleFamilyTaxBill&ReportTitle=Average%20Single%20Family%20Tax%20Bills*

Travel and Tourism

The tourist industry[10] is one of the largest industries on the Cape, experiencing consistently high growth with respect to Massachusetts as a whole (Figure 3), except for two noticeable dips, following the September 11, 2001 terror attacks, and in the aftermath of the 2008 recession (Figure 2). In 2011, it accounted for 14% of Barnstable County's Gross Regional Product (GRP). In addition, it employed approximately 8,000 workers, or nearly 20% of the county's total employment.

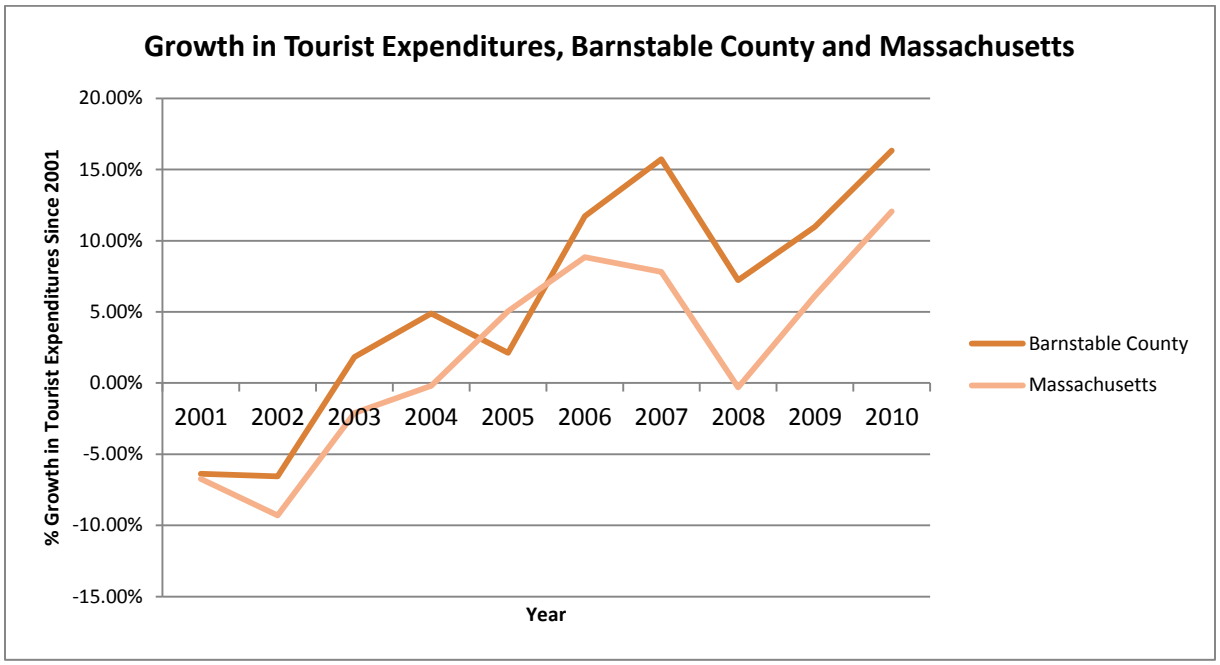

Figure 3: Tourist Revenue Growth, Barnstable County and Massachusetts

The Cape Cod National Seashore is a significant draw for domestic tourism, especially day trips and short-term stays. In 2011 there were 4,484,771 visits made, generating $175 million in expenditures and creating 1,739 jobs[11].

[10] We refer to the US Travel Association's definition of "travel industry"
[11] U.S. National Parks Service, "Economic Benefits to Local Communities from National Park Visitation, 2011," http://www.nature.nps.gov/socialscience/docs/NPSSystemEstimates2011.pdf

IV. Historical Nuclear Accidents and their Effects on Tourism and Real Estate

Serious accidents involving nuclear reactors and radiological materials vary significantly with respect to features such as affected populations, spread of radiation, knowledge of effects, and cleanup efforts. As such, it is difficult to precisely quantify the effects of a future potential event in any given location. However, a brief review of four relevant cases is useful to establish upper and lower boundaries on the impact of a similar event at Pilgrim.

Goiânia

In September 1987, the city of Goiânia, Brazil, was the site of one of the worst accidents involving radioactive materials in history: Two men broke into an abandoned clinic searching for scrap metal. Inside a radiotherapy device left in the clinic, they found a metallic cylinder, which they subsequently sold to a scrap metal dealer. Inside the cylinder was a chunk of radioactive cesium-137. It was passed around to friends and family, who were curious about the material's glow. Children ended up playing and touching the cesium, resulting in the contamination of 249 people, 20 cases of radiation sickness, and 4 fatalities[12].

Largely due to the treatment of the incident by the international media, the impact to tourism in Goiânia was massive; the number of visitors to the city declined by 40%, and visitors to areas up to an hour from the city experienced a 30-40% decline in visitors[13] in the months immediately following the accident. After a six-month cleanup, tourism levels returned to normal within the year, although the city experienced a 15% fall in GDP which did not return to baseline levels for another five years.

Three Mile Island

In 1979, a partial core meltdown occurred in one of the reactors of the Three Mile Island (TMI) Nuclear Power Station near Middletown, Pennsylvania. The accident was due to what was possibly a mechanical failure that caused water to drain from the cooling system. This resulted in a small release of radioactive gas, although it was found not to have increased the level of radiation outside the plant beyond the background level[14]. However, a state of emergency was declared and 144,000 people,

[12] International Atomic Energy Agency, "The Radiological Accident in Goiânia," Vienna 1988 http://www-pub.iaea.org/MTCD/publications/PDF/Pub815_web.pdf

[13] Kasperson, Roger, and Kasperson, J., "The Social Amplification and Attenuation of Risk," *Annals of the American Academy of Political and Social Science,* Vol. 545, May 1996

[14] U.S. Nuclear Regulatory Commission, "Backgrounder on the Three Mile Island Accident," February 2013, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

largely young children and pregnant women, were evacuated from a 5-mile radius surrounding the plant. Lost production in the days immediately after the event totaled to around $82 million, and cleanup of the site cost $1 billion and took 14 years to complete[15].

There have been several studies attempting to identify any diminution of property values as a result of the accident[16,17] but none of them found any significant effect.

Chernobyl

The worst nuclear disaster in history provides an upper bound for estimates at Pilgrim. In 1986, in what is now Ukraine, a design flaw in the reactor led to an explosion and a subsequent massive release of radioactive material, spreading fallout across large parts of Europe, with the greatest concentration located in Belarus[18]. The disaster resulted in the evacuation and resettlement of over 330,000 people, including the entire population of the town of Pripyat[19].

The economic costs of the disaster have been massive. Large areas remain deserted since the accident; property in the affected regions close to the plant is essentially valueless. The accident also forced industrial and agricultural land into disuse, resulting in a sharp decline in output in both sectors. In addition, the resettled populations suffer from high unemployment and are supported out of state funds. The impact is still being felt even decades later; the IAEA estimates that between 1991 and 2003, Belarus spent $13 billion on Chernobyl, and an estimated total of $235 billion since the accident occurred.

The area around Chernobyl was primarily rural and agricultural, with no tourist industry to speak of; ironically, there is now a small cottage "nuclear tourism" industry springing up in the surrounding towns, catering to those brave enough to explore the site. However, in other areas of Europe, there was found to be a large negative effect on tourism; Sweden lost an estimated 2.5 billion SEK ($389 million) in

[15] "14-year Cleanup at Three Mile Island Concludes," *The New York Times*, August 15 1993 http://www.nytimes.com/1993/08/15/us/14-year-cleanup-at-three-mile-island-concludes.html
[16] Nelson, Jon, "Three Mile Island and Residential Property Values: Empirical Analysis and Policy Implications," *Land Economics* 57:3 August 1981
[17] Gamble, Hays, and Downing, R., "Effects of the accident at Three Mile Island on residential property values and sales," *Journal of Regional Science* 22:4, November 1981
[18] International Atomic Energy Agency, "Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts," 2003-2005
[19] International Atomic Energy Agency, "Frequently Asked Chernobyl Questions," http://www.iaea.org/newscenter/features/chernobyl-15/cherno-faq.shtml

tourist revenue from 1986 to 1989[20] as a result of the disaster due to the perceived threat of fallout, despite being approximately 700 miles away from the site

Fukushima

On March 11, 2011, the massive Tōhoku earthquake shook western coast of Japan. The quake produced a tsunami which struck the coast 10 to 20 minutes later, with waves as high as 133 feet and reaching nearly six miles inland in some areas[21]. There were six reactors at the Fukushima Daiichi plant, of the GE BWR type; only three of these were operating at the time of the earthquake. As the quake knocked out the transmission lines to the plant which provided power to the cooling system, the reactors underwent automatic shutdown, while the emergency power system, consisting of 12 diesel generators, continued to pump coolant into the reactor; however, the water from the tsunami breached the seawalls in the surrounding harbor and flooded all but one of the diesel generators. Without sufficient coolant, the reactors began to overheat; the backup coolant system, an isolation condenser, was unable to activate due to the lack of external power. When the temperature rose high enough, the zirconium cladding surrounding the fuel rods in the core reacted with steam to produce hydrogen, which then caused a series of explosions inside the reactors and releasing large amounts of radioactive material into the environment.

After the tsunami, the government of Japan declared a 20km (12mi) exclusion zone surrounding the plant, as well as several more when it was found that the radiation plume had been blown northwest. The number of evacuees due to the meltdown numbered more than 157,000; as of March 2013, 32,000 were still living in temporary housing and 59,000 in subsidized apartments; about 54,000 of these residents will be unable to return home by 2017[22]. This represents massive losses in terms of employment, purchasing, and the cost of the subsidy, in addition to the loss of all economic activity within the evacuations zones and compensation for property that is uninhabitable, inaccessible, or severely devalued due to contamination. In addition, the reactor area is flooded with large amounts of radioactive water, pumped into the site to cool exposed fuel rods.

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[20] Olsson, Christina, and Hultkrantz, L., "Chernobyl Effects on Domestic and Inbound Tourism in Sweden – A Time Series Analysis," *Environmental and Resource Economics* 9:2, 1997

[21] National Oceanic and Atmospheric Administration, "Japan's 'Harbor Wave:' The tsunami one year later," http://www.noaa.gov/features/03_protecting/japantsunami_oneyearlater.html

[22] Kasai, Tetsuya, "About 60 percent of Fukushima evacuees cannot return home by 2017," *Asahi Shimbun,* March 11, 2003 http://ajw.asahi.com/article/0311disaster/recovery/AJ201303110005

The Japanese tourist industry experienced a major decline as a result of the accident, falling by 30% in 2011, and Fukushima Prefecture saw nearly an 80% drop in visitors. Though the industry is recovering in many parts of Japan, there are several tourism-heavy areas that have seen visits remain between 40% and 80% of what they were before the accident.

V. Risk Factors at Pilgrim

Although a complete discussion of the technical details and operations of PNPS is beyond the scope of this report, it would be useful to briefly review the reactor's functioning and any potential major accident risks.

Pilgrim operates a single General Electric Boiling Water Reactor (BWR) Type 3, with a Mark I containment device. The reactor design was introduced in 1965, and this particular reactor was licensed in 1972. The BWR system is relatively simple; the reactor, which contains nuclear fuel, is used to heat purified water into steam. The pressurized steam forms above the reactor core, and turns a system of turbines, which generate electricity. The steam then travels through a series of condensers, which condense it back into water which is pumped back into the reactor to cool the core by boiling off into steam.

Risks of a Major Accident

In case of an emergency, the reactor is designed to automatically shut down by moving graphite control rods into the core. A reactor shutdown is itself inherently dangerous; due to radioactive decay, the temperature of the nuclear fuel inside the reactor core continues to rise. This makes the station's connection to offsite power critical, since the cooling systems must be able to run even when the station is not generating. During a loss-of-coolant accident (LOCA), an inability to cool the reactor after shutdown leads to overheating that eventually damages the reactor if left unchecked.

As detailed above, this is appears to be what happened to the reactors at Fukushima; the earthquake knocked out the transmission wires connecting the cooling system to offsite power, triggering an automatic shutdown. The backup diesel generators activated as planned, but, due to their location beneath the turbine housing, were flooded minutes later by the tsunami. The loss of backup

power due to flooding rendered the backup cooling system inoperable, leading to an uncontrolled rise in temperature, boiling off of reactor coolant, and complete core meltdown[23].

This has prompted concerns that the same event could be repeated at Pilgrim, which utilizes the same reactor type as Fukushima Daiichi. Despite this similarity, it is important to note that the meltdown at Fukushima began as a failure of the *cooling system,* rather than a failure of the reactor design itself, which actually shut down automatically, as designed, at the onset of the earthquake. Pilgrim does not use the isolation condenser (IC) system used in Fukushima for backup cooling (this mechanism, located above the reactor, transfers excess heat to clean steam that is released to the atmosphere), and the generators that provide backup power in case of a blackout are elevated above sea level in the case of a flood; the backup systems can also be operated without power. As a last resort, water can be pumped in directly from Cape Cod Bay[24]. If a LOCA were to occur, it almost certainly could not happen in the same way, i.e. as a result of flooding rendering the cooling system inoperable. This, of course, does not rule out the possibility of other "beyond design-basis" events; extreme conditions which are, by their nature, unpredictable and thus cannot be accounted for during facility design, such as the occurrence of Tōhoku, the fourth-most powerful earthquake in recorded history.[25] The NRC estimates that the annual risk for an occurrence of an earthquake powerful enough to damage Pilgrim's reactor core is 1 in 14,493, the second-highest risk factor for any nuclear reactor in the United States.

Spent Fuel

The greatest accident risk at Pilgrim NGS (and at aging nuclear reactor facilities in general) is increasingly crowded spent-fuel pools. Spent nuclear fuel remains highly radioactive, and is stored in deep pools of water at the site itself. Initially, these pools were designed to hold the spent fuel rods

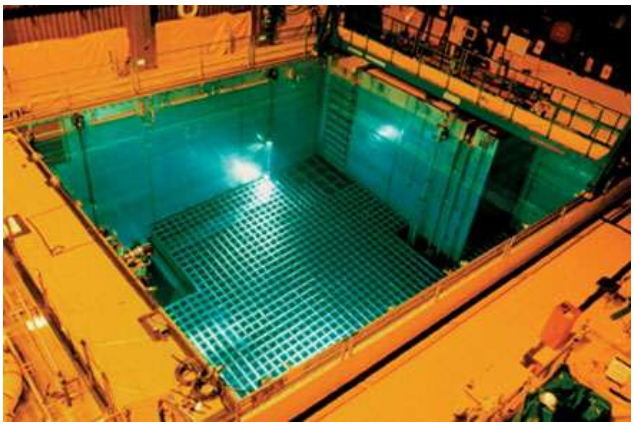

Figure 4: Spent fuel storage pool (Source: Union of Concerned Scientists)

[23] Strickland, Eliza, "24 Hours at Fukushima," *IEEE Spe*
http://spectrum.ieee.org/energy/nuclear/24-hours-at-fukushima
[24] U.S. Nuclear Regulatory Commission, "Safety Evaluation Report Related to the License Renewal of Pilgrim Nuclear Power Station," November 2007
[25] "New USGS number puts Japan quake at 4th largest," CBS News, March 14, 2011, http://www.cbsnews.com/stories/2011/03/14/501364/main20043126.shtml

until they "cooled" enough to be transported to a deep geological repository, to be stored there for thousands to millions of years. The cancellation of the planned Yucca Mountain waste repository by the Obama Administration[26] then effectively turned every nuclear power station in the country into an indefinite-term high-level nuclear waste storage site, until a suitable replacement for Yucca Mountain can be planned and built.

Originally, the spent fuel at Pilgrim was stored in low-density racks, with a maximum capacity of 880 fuel assemblies. As the spent fuel piled up, the industry switched to using high-density storage racks[27], and the maximum capacity at Pilgrim increased to 3,859. In the summer of 2013, Entergy approved the transfer of the least-radioactive assemblies into dry cask storage in order to free up room for newly spent fuel.

The high-density configuration increases the risk of a pool fire, in which a fall in the water level in the pool allows decay heat to reach a critical level, further boiling off coolant. Eventually, the rising temperature melts the zirconium fuel cladding, creating the risk of the same type of hydrogen explosion that initially damaged the Fukushima reactor core, resulting in a release of radiation. Given the amount of fuel stored on-site, the release has the potential to be quite large.

Planned Emergency Procedures

Currently, Entergy maintains emergency plans for the NRC-mandated 10-mile Emergency Planning Zone surrounding the station. The zone includes the towns of Duxbury, Kingston, and

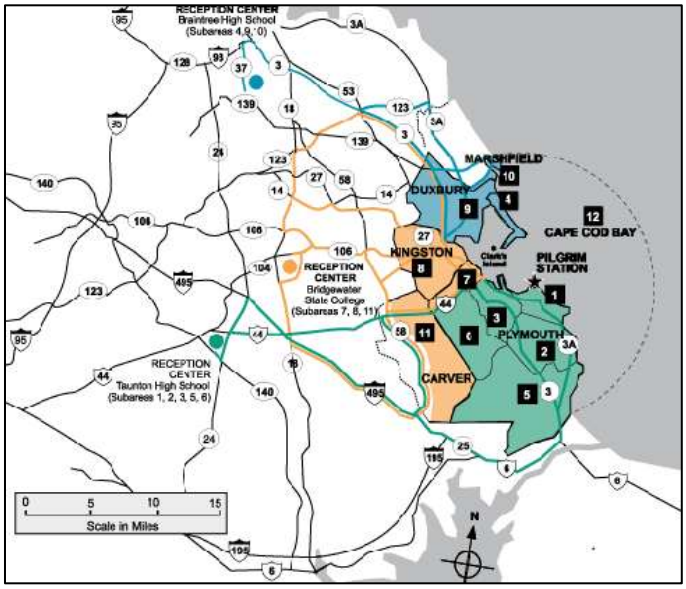

Figure 5: Evacuation Planning Zone around Pilgrim. Source: Entergy Corp

[26] Northey, Hannah, "GAO: Death of Yucca Mountain Caused by Political Maneuvering," *The New York Times*, May 10, 2011, http://www.nytimes.com/gwire/2011/05/10/10greenwire-gao-death-of-yucca-mountain-caused-by-politica-36298.html

[27] Thompson, Gordon, "Comments on the US Nuclear Regulatory Commission's Draft Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor," Institute for Resource and Security Studies, August 1, 2013

Plymouth[28] (Figure 5). There exist no emergency evacuation plans for areas outside the 10-mile EPZ, including Cape Cod.

At Fukushima, the initial EPZ-equivalent of 10km (6 miles) was expanded to 20km (12 miles) after it was realized that the radiation had spread much further than the initial planning area. Eventually, those in areas from 20-30km (12-18 miles) from the plant were asked to voluntarily evacuate, while in some heavily irradiated areas, it was mandatory.

If a similar situation were to occur at Pilgrim, both of the bridges that connect the Cape to the mainland are within 20 miles of the plant, potentially putting them within the area of contamination and evacuation. If this happened during the tourist high season during late summer, it could mean up to 500,000 people trapped with a shelter-in-place order for an indefinite period of time, until a proper evacuation procedure could be executed. In addition, a large fraction of the Cape's population and business centers lie in or close to the 20 mile radius; the lack of a systematic emergency response plan may incur heavy costs, especially in terms of image and perception. The scenario in which contamination spreads towards the bridges is included in the calculations below.

VI. Estimated Impacts on the Cape Cod economy

Estimations for the economic impacts of a disaster occurring at the Pilgrim reactor are given here. There are two main cases to be examined; the first is a small-scale release of radiation (in the sense that radiological contamination does not extend to Cape Cod itself). The second is a large-scale meltdown-type event, either due to a large, uncontrolled pool fire or some other beyond-design-basis event, such as human error or terrorism.

Case 1: Small-Scale Event

The assumptions for the first case are as follows:

- The accident is centered at the plant itself and occurs during the current year (2013), using simple revenue, employment, and GDP growth projections.

[28] "Emergency Planning Zone," http://www.pilgrimpower.com/get-the-facts/emergency-planning.html

- The accident involves a relatively minor release of radioactive material, in that the effects are primarily on the basis of perception and image, rather than actual radiological contamination.
- Disaster response proceeds as planned, i.e. evacuation from the 10-mile Emergency Planning Zone. This does not encompass any part of the Cape, but does come near Sagamore Bridge. Due to the prospect of shadow evacuations[29] jamming up the only remaining bridge, it is likely that Cape Cod will receive a shelter-in-place order[30].
- Additionally, due to the proximity of the Sagamore and Bourne bridges to any potential impact area, we assume that the accident will have an effect on all of Cape Cod tourism and recreation, since all visitors must pass over one of the bridges.
- Individuals are informed enough about the accident to make a decision (in other words, no attempt at covering up the extent of damage) on whether to travel to an affected area.
- Owners of seasonal and second houses have fewer incentives to remain at the Cape.
- Cleanup takes one year, and tourist revenue does not begin to return to normal until after the disruption is cleared, i.e. after cleanup is completed.
- The event results in moderate-to-severe negative media coverage.

The effects of radiological contamination on tourism and tourism-related industries are highly variable—they depend on factors such as the perception of competence (as well as actual competence) during cleanup efforts, the image of the area, and a range of other psychological and social effects. In other words, outside of the direct health effects from a radiological release, it is the *perception* of contamination that might induce a potential visitor to choose to vacation elsewhere, even in cases where actual radioactive contamination is minimal or absent.

The return of tourist activity to normal levels after a disruption is similarly affected by what could be considered damage to the Cape Cod "brand" and misperceptions about risk among potential visitors. The proximity of the station to the only bridges that allow access to the Cape presents a unique problem, in that any potential visitor has to travel near the site of a nuclear accident to get to their vacation destination.

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[29] Donn, Jeff, "Nuclear Evacuation Study Shows That Communities Outside 10-Mile Zone May Bog Down System," *The Huffington Post* September 26, 2013

[30] Remarks by MEMA director Kurt Schwartz at the Barnstable County Regional Emergency Planning Committee Oct. 3, 2012 Harwich Community Center, http://capedownwinders.org/pdf/MEMA_Dir_Schwartz_BCREPC_121003.pdf

The Goiânia accident caused a sharp decline, though tourist levels returned to normal within a year. In addition, it had impacts on areas far away from any contamination; this forms the lower-bound scenario. The upper-bound scenario is formed on the basis of the magnitudes of declines in tourism in areas near Fukushima[31]. These calculations include the direct effects only; induced and indirect effects on consumption and employment will amplify the effects of the disaster. Based on studies done on the impact of ecological disasters on tourist industries[32,33], a return to the baseline level of revenue growth is estimated to take between 15 and 36 months. The decline in tourist revenue is also accompanied by the reduction in tourism-related income, sales, and excise taxes collected by the State of Massachusetts.

Table 2: Small-scale event: Impacts to tourist expenditures and tourism-sourced state tax revenues (Millions of 2011 dollars)

Impact Assumption	Return Duration	Expenditures 2013-2023 (projected)	1-Year Impact	5-Year Impact	State Tax Revenues	1-Year Impact	5-Year Impact
40%	1 year	$11,376	-$406	-$741	$272	-$14	-$23
	3 year	$10,864	-$406	-$1,252	$254	-$14	-$41
60%	1 year	$11,096	-$609	-$1,020	$261	-$21	-$34
	3 year	$10,442	-$609	-$1,674	$233	-$21	-$62
Baseline Estimate		**$12,117**			**$295**		

Effects on Property Values

The relationship between radioactive releases and residential property values has been the topic of several studies, most often in the contexts of transportation of nuclear waste and nuclear power plant siting[34]. However, the results are still largely inconclusive. Authors investigating the aftermath of Three Mile Island could find no link between the release of radiation and declining property values, despite a successful class action lawsuit against Metropolitan Edison claiming that property diminution had occurred. Several studies concerning the now-cancelled Yucca Mountain nuclear waste repository found a strong link; others found none.

[31] Japan Tourism Agency, "White Paper on Tourism in Japan," 2012, http://www.mlit.go.jp/common/000221177.pdf

[32] Summarized in Oxford Economics, "Potential Impact of the Gulf Oil Spill on Tourism," 2009, http://www.ustravel.org/sites/default/files/page/2009/11/Gulf_Oil_Spill_Analysis_Oxford_Economics_710.pdf

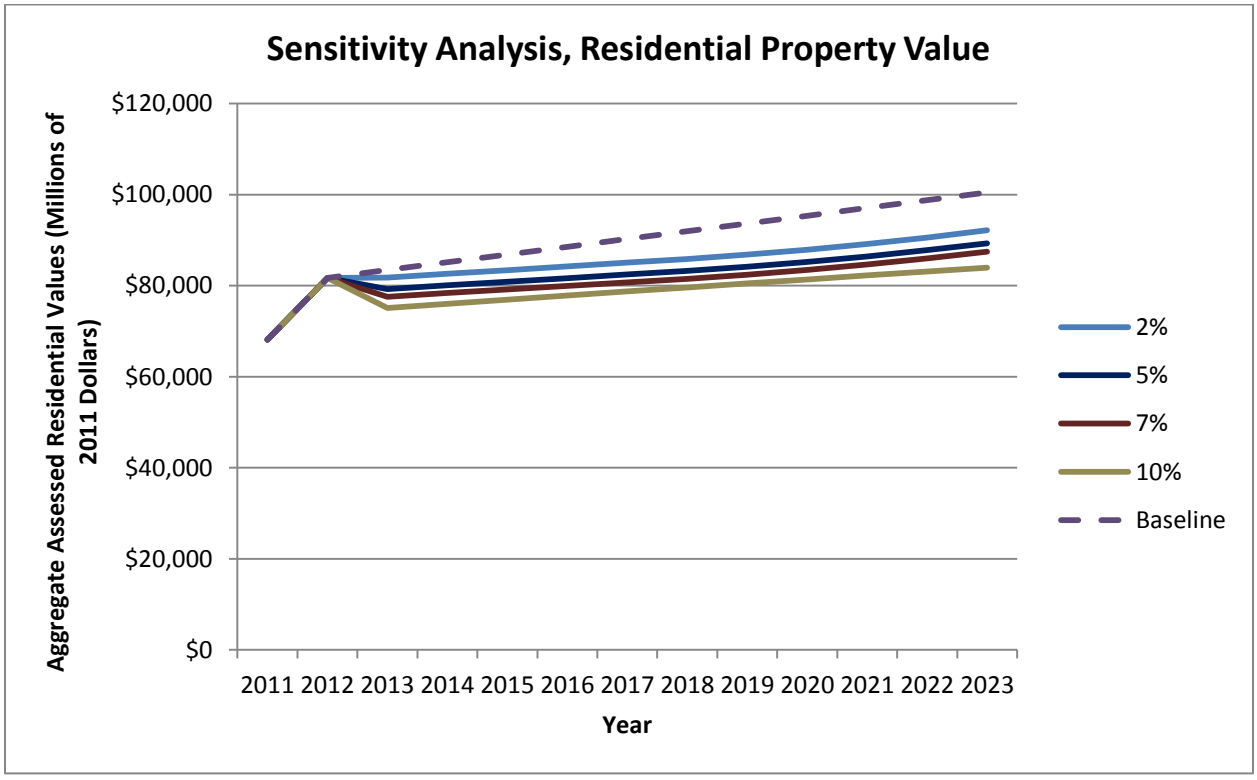
[33] Pelling, Mark, O. Alpaslan, and S. Barakat, "The macro-economic impact of disasters," *Progress in Development Studies* 2:4, 2002

[34] Bezdek, Roger, and R. Wendling "The impacts of nuclear facilities on property values and other factors in the surrounding communities," *International Journal of Nuclear Governance, Economy, and Ecology* 1:1, 2006

However, it is likely that, due to the nature of the Cape Cod economy, and the positioning of Pilgrim NGS near the entry points to the Cape, an accident at the plant would have a negative effect on the value of residential property. Contamination affects property values primarily through the *perception* of risk and the secondary effect of declining profitability of land use. After Fukushima world opinion has taken a decided turn against nuclear power, and the possibility of nuclear accidents, and one of the most consistent findings in the literature is the link between negative publicity and significant property value diminution[35].

Various estimates have been made for the effects of radiation releases on property values. These are likely to be highly dependent on the area which is exposed; the sensitivity analysis establishes upper and lower boundaries for significant effects at 2% and 10%.[36] It is assumed that for some time after the incident, property would appreciate in value at a rate much lower than the baseline, after which restored confidence would begin to bring it back.

Figure 6: Small-scale event: Estimated residential property appreciation for four different scenarios



[35] Olshansky, S., B.A. Payne, and T.E. Segel, "The Effects on Property Values of Proximity to a Site Contaminated with Radioactive Waste," *Natural Resources Journal* 27, Summer 1987

[36] Beyea, Jan, "Report To The Massachusetts Attorney General On The Potential Consequences Of A Spent Fuel-Pool Fire At The Pilgrim Or Vermont Yankee Nuclear Plant," May 25 2006

Table 3: Small-scale event: Potential lost value of residential property

Impact Assumption	Projected 2023 Value	Initial Impact	Total Impact 2013-2023
2%	$92,139	-$1,668	-$16,899
5%	$89,319	-$4,171	-$19,719
7%	$87,438	-$5,840	-$21,600
10%	$83,975	-$8,342	-$25,063
Baseline Estimate:	**$109,038**		

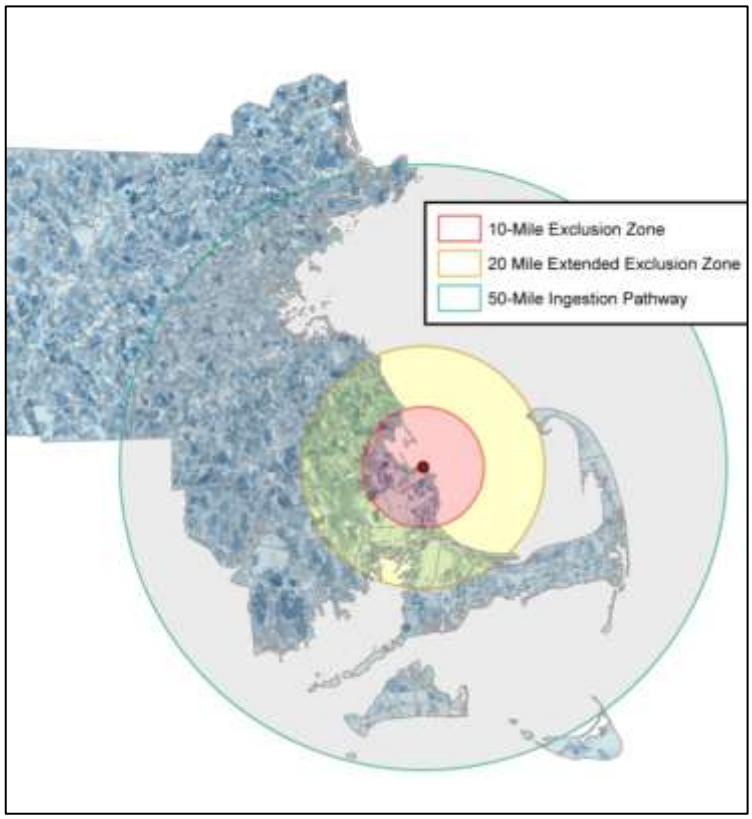


Figure 7: Population distribution map of Eastern Massachusetts, showing 10, 20, and 50 mile radii around Pilgrim. Data Source: U.S. Census

Case 2: Large-Scale Event

This scenario involves a large, uncontrolled release of nuclear material, of the type produced by a core meltdown or a severe spent fuel accident. In this case, there will be direct and immediate losses due to the evacuation procedure, and ongoing losses as a result of the disruption to tourism and general economic functioning on the Cape. Again, the peculiar situation of having only two routes by which to access the county (and having both of these being inside the area of potential impact) necessitates a broad approach to estimating the effects.

Assumptions:

- At Fukushima, the radiation plume caused by the meltdown extended up to 30 km (18 miles) northwest of the plant, beyond the initial 20 km (12 mile) evacuation zone. It is assumed that this might be the case in a potential disaster scenario for Pilgrim as well. Though an analysis of possible wind dispersion of radioactive materials is beyond the scope of this report, a potential extended impact zone can

be mapped out to a 20 mile radius from the plant. In practice, this simulates a worst-case scenario in which wind blows the radioactive plume to the south, necessitating the evacuation of the most densely populated areas of the western Cape.

- The mix of tourist and non-tourist businesses remains relatively constant across towns in the Cape.
- The value of property and businesses inside the exclusion zone is assumed to be zero. Unsurprisingly, there was no data available on appraisals of land inside areas after evacuation.
- All evacuees will not be returned by the end of the analysis period. At the time of writing, some 60% of Fukushima evacuees were still unable to return to their homes; in the case of Chernobyl, the surrounding areas are deserted, decades later.
- Due to the location of both bridges leading to the Cape inside the extended exclusion zone, it is assumed that tourist visits will be effectively halted until decontamination is completed, after which they return to baseline levels after a period of time.
- Cleanup takes five years.

The three boundary cases used for this sensitivity analysis are:

a. *Low impact*: This is what could be termed the "best-case" scenario. In this case, evacuation occurs, but mitigation and resettlement proceed on schedule; as areas are deemed free from contamination, the evacuees are allowed to move back, driving some economic growth before cleanup operations are completed, and once they are, recovery proceeds apace, and the tourist industry may be able to bounce back to normal in a manner similar to the small-scale release.
b. *High impact*: This scenario models a serious accident at Pilgrim, similar to Fukushima. Exclusion zones remain nearly fully active for the duration of the cleanup, and the presence of lingering contamination indefinitely prevents many evacuees from returning. The threat of contamination seriously impacts tourism, incentivizing people to travel to somewhere else rather than risk the Cape; although travel eventually begins to increase, it is uncertain whether they will return to their previous level. Damage to businesses is significant and long-lasting.
c. *Highest impact*: The highest impact scenario represents the upper boundary of the sensitivity analysis; it represents the absolute worst-case scenario. Contamination is heavy and long-lasting, and as a result tourists abandon the Cape completely. The exclusion zone remains as such indefinitely, uninhabitable for perhaps hundreds of years, and private enterprise is severely limited, if even present. This scenario's parameters are designed from the lessons of Chernobyl.

There are 103,703 people living withing within the 10-mile Emergency Planning Zone currently in place, 343,602 within 20-mile extended evacuation area, and 4,034,044 in the 50- mile Ingestion Pathway Zone. Fifty miles was also the evacuation radius recommended to Americans in Japan by the American Embassy during the Fukushima incident[37].

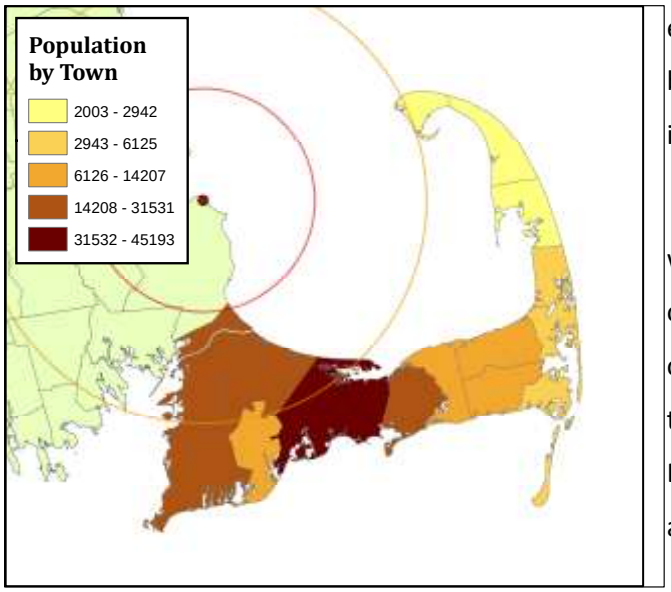


Figure 8: Population distribution by town, showing potential impact zone

Within Barnstable County, 3,879 people live within 10 miles, 51,329 within 20 miles, and all 215,888 of its residents live within 50 miles of the plant. A spread of radiation within the 20-mile zone will primarily affect the towns of Falmouth, Bourne, Sandwich, Mashpee, and Barnstable, an area of the Cape containing property with an assessed value of $50 billion. In 2013, businesses in these towns had estimated revenues of $6.4 billion and employed 44,979 workers in local industries with a total payroll of $1.6 billion[38]. This area hosts most of the population and economic activity of the Cape, and its evacuation would cause significant immediate losses: an 83% decline in Barnstable County's Gross Regional Product (GRP) and a 1.5% fall in the Gross Domestic Product (GDP) of Massachusetts as a whole (GDP and GRP are measures of the total amount of goods and services produced by the economy—GRP is at the regional level, in this case the county, and GDP is at a larger level, in this case the state). Table 4 shows the effects on business activity inside the evacuation zone, calculated using Geographic Information System software:

[37] Cox, Amanda, Ericson, M., Tse, A., "The Evacuation Zones Around Fukushima Daiichi Nuclear Plant," *The New York Times*, March 25, 2001

[38] Author's calculations based on the 2007 Economic Census and GIS Census data by census tract

Table 4: Large-scale disaster: Business activity within the evacuation zone (Millions of 2011 Dollars)

Impact Assumption	Sales and Receipts 2013-2023 (projected)	1-Year Loss	5-Year Loss	10-Year Loss
Low Impact	$16,588	-$5,893	-$26,520	-$42,858
High Impact	$5,035	-$5,893	-$30,453	-$54,411
Highest Impact	$0	-$5,893	-$30,453	-$59,446
Baseline Estimate	**$59,446**			

Aside from the direct losses due to the evacuation, a nuclear disaster would have an enormous impact on tourism, both to Cape Cod and Massachusetts as a whole. Areas surrounding Fukushima in Japan reported up to a 60% decline in tourist visits a month after the accident[39]. However, due to the location of the Bourne and Sagamore bridges within the 20-mile exclusion zone, nearly all tourism to the Cape will probably cease until evacuation orders are lifted, though these routes will likely be first on the list for decontamination efforts. Effects on the tourist industry are summarized in Table 5:

Table 5: Large-scale disaster: Effects on Cape Cod tourist revenues (Millions of 2011 dollars)

Impact Assumption	Expenditures 2013-2023 (projected)	1-Year Loss	5-Year Loss	10-Year Loss
Low Impact	$9,829	-$769	-$2,204	-$2,288
High Impact	$5,684	-$769	-$3,878	-$6,432
Highest Impact	$19	-$1,014	-$1,369	-$12,098
Baseline Estimate	**$12,117**			

In order to calculate the expected decline in tourist expenditure, the estimated value of the tourist industry in the evacuation zone was disaggregated in order to avoid double-counting. In both the low and high impact scenarios, the initial 80% decline in tourism reported in Fukushima Prefecture was used to calculate the impact; the first with a relatively fast recovery time, as seen in Fukushima, and the second assumes a more cautious return of travelers. The highest-impact scenario assumes a situation in which the contamination, or perception of contamination, is too great for the survival of the tourist industry, although it does allow for a small amount of nuclear tourism after the initial cleanup period (e.g., as in Chernobyl).

[39] Birmingham, Lucy, "Is Post-Fukushima Japan Safe for Tourists?" November 2011 http://content.time.com/time/world/article/0,8599,2099119,00.html

The total effect on Barnstable County's GRP of both the decline in tourist revenue and the evacuation of what amounts to a large part of the Cape's central business district is summarized in Table 6. Also included is the effect on Massachusetts' GDP and GDP growth.

Table 6: Large-scale disaster: Total effect on Barnstable County GRP and Massachusetts GDP

Impact Assumption	Barnstable County GRP 2013-2023 (projected)	1-Year Loss	5-Year Loss	Losses 2013-2023	Massachusetts GDP 2013-2023 (projected)	Avg Effect on GDP growth
Low Impact	$38,775	-$6,661	-$28,725	-$45,146	$4,629,453	-0.98%
High Impact	$23,077	-$6,661	-$32,364	-$60,844	$4,613,755	-1.31%
Highest Impact	$12,377	-$6,907	-$33,733	-$71,544	$4,603,055	-1.53%
Baseline Estimate	**$83,920**				$**4,674,599**	

Additionally, the direct effect of the decline in Cape Cod's output reduces Massachusetts' total tax revenue due to lost sales and income:

Table 7: Large-scale disaster: Impact on Massachusetts state tax revenue (Millions of 2011 Dollars)

Impact Assumption	Income Tax 2013-2023 (projected)	1-Year Loss	5-Year Loss	Losses 2013-2023	% decline from baseline
Low Impact	$252,719	-$667	-$2,989	-$4,881	-1.89%
High Impact	$250,918	-$667	-$3,376	-$6,682	-2.59%
Highest Impact	$249,662	-$692	-$3,519	-$7,938	-3.08%
Baseline Estimate	**$257,600**				

Summary Results

1. In the case of a *small-scale* incident involving the release of nuclear materials:
    a. Potential losses to the tourism industry on Cape Cod from $682 million-$1.7 billion over 5 years, depending on mitigation time and the nature of the release, resulting in a loss of between $23 and $42 million in sales and income tax revenue.
    b. Potential losses in property values depend highly on publicity of the incident; given the freshness of Fukushima, this will likely be very high, especially if it occurs during the tourist season, incurring between $16.9 billion and $25 billion in loss of value to residential property.
2. In the case of a *large-scale* incident involving the release of nuclear materials:

a. The 10-mile Emergency Planning Zone will have to be evacuated and most likely a 20-mile extended area as well. This 20-mile zone encompasses a large fraction of Cape Cod's resident population as well as most of the region's economic activity. The economic costs over 10 years to the Cape of evacuating this region are: between $42.9 billion and $59.4 billion; the evacuation and resettlement of 48,727 people; and, the destruction of $8.8 billion to $11 billion in real property. There are also additional indirect effects, such as the loss of $1.6 billion in earnings which could have been used for consumption.
b. Revenues from domestic tourism would fall by $2.2 to $12 billion over the next 10 years, contingent upon the effectiveness of the mitigation effort and the perception of the safety of Cape Cod.
c. Taken together, these two effects alone will account for a significant fall in Gross Regional Product; between $45 and $71 billion over 10 years.
d. The *direct* impact to Massachusetts' tax revenue over 10 years is a loss of $4-$7 billion.
e. Both bridges that access the Cape fall within the 20-mile extended exclusion zone. Depending on the extent of the contamination, this will have drastic effects on tourism; if the only route onto the Cape is either perceived to be irradiated or inaccessible due to an exclusion zone, tourist revenue will decline essentially to zero.
f. Plymouth's status as "America's Hometown" will likely be irreversibly damaged, as the area becomes associated with the nuclear disaster, and families and retirees will likely look elsewhere for vacationing and real estate.

Further Considerations and Conclusion

- Although an estimation of the indirect and induced impacts of a disaster is beyond the scope of this report, it is expected that those effects will be at least as severe as or greater than the direct effects estimated above. Although no major industry on Cape Cod supplies inputs to other industries, induced effects would be significant; Dollars spent by workers displaced by the disaster will no longer circulate into the regional economy, causing a drop in demand and further falls in county GRP and state GDP.
- Without a clear disaster planning strategy for areas outside of the current 10-mile EPZ, it is difficult to predict conditions after a disaster, given Cape Cod's geography. "Shadow-

> evacuations" would certainly cause traffic to be impassable on the two two-lane bridges connecting the Cape to the mainland, potentially leaving up to a half-million (during tourist season) stranded. Restrictions in travel and imports to the Cape would also result in an increase in prices.

The estimates presented here represent only a broad selection of possible outcomes; due to the fact that events such as these are relatively rare, the exact determinants of the effects on the surrounding communities are still difficult to quantify. However, by concentrating on simply the key industries of the Cape, we obtain a conservative estimate of the potential impacts of both a small-scale and large-scale disaster. In the former, up to $1.6 billion are directly at risk, and in the latter, up to $71 billion. It is clear that, given the large potential losses, reactor's age, and especially the conditions of the spent-fuel pool, further evaluation of the safety of the plant is required.